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THE SCIENCE PRESS

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SCIENCE

FRIDAY, JUNE 18, 1920

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THE SURVIVAL OF THE UNLIKE[1]

SOME years ago, studying the agaves or century plants of the West Indies, I found that they represent not only many species but numerous rather distinct groups, and that the aggregates of individuals that we call species, and of species in these larger groups, resemble and differ from one another in a sort of proportion to the depth of water between the islands on which they are found, which was translated into differences somewhat proportionate to the length of time that their habitats have been separated by water barriers.

Those of near-by and apparently rather recently separated islands were not found to differ progressively and adaptatively in a single character such as flower-shape or size of seed-vessels nor was there a correlated difference in these respects, but sometimes one and sometimes another such character was different, while no indication was evident that the plants were not living under essentially identical conditions so far as pollination and dissemination are concerned.

When the idea of organic evolution was presented before the Linnean Society in 1858 in a convincing way, by Darwin and Wallace, the latter spoke of the process as a survival of the fittest, and the former, as the result of natural selection, in the struggle for existence which effects kinds or species as well as individuals of living things.

The dissociation of parts of the ancestral stock of these West Indian agaves without any marked climatic difference in their homes appeared to me to have left each final island with a stock essentially in harmony with its environment and capable of deviating considerably in flower and fruit proportions from

[1] Address of the president before the Illinois Chapter of the Society of the Sigma Xi, May 19, 1920.

the parent type without derangement of this harmony. I was unable to see that either flower or fruit change within the observable limits rendered its possessor either better or less fitted to survive. Deviation from the type appeared to have followed some innate tendency and to have been possible in quite different directions within rather wide limits without rendering its possessor either more or less fit to survive. Within such limits, the changes of form seemed to have been free to wander at will along a number of differentiating paths.

These plants apparently illustrate the survival of the equally fit, though unlike, rather than of the fittest whether alike or dissimilar, under the operation of Darwin's selective process which would weed out promptly those not really fit to meet the general conditions of life, while permitting secondary differences to appear and persist for a very long time.

This is a rather self-evident presentation of one of the physiologist's exasperating troubles, the controlling existence of a harmonious optimum as he calls it, in conformity with which his cultures succeed best under conditions that sometimes differ annoyingly from those that he has reason to believe are the optima for the individual functions that he wishes to investigate experimentally one by one. It recalls forcibly, though not paralleling, the dominance of certain features in unskilfully made composite photographs. It parallels the transformation of that peculiar function, productive investigation, to the promotion of which the society of the Sigma Xi devotes its efforts. Conditions being collectively favorable, many differences that appear, whether fluctuating or mutant, represent variation rather than real evolution.

Apt in aphorisms, Bailey once hit on the expression survival of the unlike for that outcome of natural selection or the survival of the fittest to which the name evolution usually is applied. It calls up the picture of a changing or changed environment which eliminates the harmoniously fit of the past and allows their successors of the present to fight it out among themselves for the final perpetuation or disappearance of individual idiosyncrasies that they may have inherited or acquired.

The organic change may or may not be abrupt because the change in environment may or may not have been sudden: very commonly it appears to have been gradual. Its product may or may not please us. Except through the artificial selection that we apply in the broad field of agriculture, we have not intentionally changed the controlling conditions. The great response of organic nature is not conformed to our wishes or ideals but to that innate law of living matter that compels it to perpetuate itself and the forms through which it may best do this. The product is as varied in effectiveness as in form, but it tends to efficiency in peopling the earth and in making use of by-products and waste as well as of the raw materials offered by inorganic nature.

The lesson of organic evolution is at once discouraging and hopeful: discouraging as showing that the individual or the kind that can not keep to the gait must fall out of the procession; encouraging as showing that keeping the pace is not necessarily keeping in step; and hopeful in that as the world of dead matter changes, the world of living matter effectively shifts its life processes and vital machinery toward ultimate conformity to the great opportunity that is its own for the moment—a conformity which if perfect would eliminate finally disharmonies, and realize a perfect teleology of self-contained adaptation.

Even inert matter is coming more and more to evolutionary recognition, as its heavier elements are found to be older and more complex, their unaided combinations to tend into an instable complexity that approaches the surpassingly labile living matter, and their dissociated particles to gather through unmeasured space into solar systems perhaps all at some time as capable of supporting life as our own is known to be at present. The greatest law of nature seems to be that of spontaneous aggregation of matter into complex forms and of the shaping of these into efficient forms.

We are given now to naming our chosen activity—whether in science, literature, history or art—research, and the dictionaries permit each of us who cultivates it productively, to be spoken of as a researcher. I do not like the words: the second is not euphonious to my ear; and the first is too suggestive of the cyaniding of the tailings of an abandoned mine or of the sifting of what may be called variously a dust-bin or an ashpile. Unfortunately it is true that neither mining nor furnace management nor refuse collection is exhaustive, and re-search of their refuse must be made over and over again as values change or methods are improved. But I like to think of our profession as that of investigation and of our colleagues as investigators —trailing the truth wherever it must be sought—through the débris left by our predecessors when necessary, but by preference in the virgin field of nature.

This profession in its history parallels in many ways that of a phylum of plants or of animals. It has had its days of fruitless aimlessness; some of its products appear grotesque to us of to-day; some of its branchlets, like those of a cottonwood or an elm in autumn, have been cast off, perhaps to the benefit of the whole, when they did not continue to produce in proportion to their early promise or in comparison with others more favorably environed. Some, too favorably circumstanced, may even have been pruned out as unfruitful or destructive of a collectively effective balanced symmetry because of their rank vegetation. Natural and artificial selection have worked on it since its beginning, and there is little reason to suppose that they will not continue operative until its end.

The parallel may be carried somewhat further than one would carry it at first thought.

Long before man began to find the products of organic nature profitable—indeed long before his appearance on the scene—plants had developed the power of making food and of applying it to their needs; and animals had acquired the habit of carrying its use into a much more dynamic field. The greatest tilth of this field is by man, the present culmination of the family tree of our living world; and what the struggle for existence among his more lowly relatives had produced, that he could use, he has selected and favored and modified to his greater benefit.

The strife between purposeful intelligence and productive capability, in which within limits the former is fore-ordained to dominate the latter, is not peculiar to human civilization and to the dominance of man over man: it reaches far into his relations with his fellow-creatures of lesser endowment. He has shaped them to his needs or fancies, very often in opposition to the selective law of nature; he has multiplied, at the expense of others, those that he fancied, and thereby has increased the power of the earth to support human life and human activity far beyond its unaided capacity; he has become a potent factor in natural selection, and will continue operative as long as he does not kill the goose that lays the golden egg. It is significant that what he does not use, directly or indirectly, he commonly permits to exist through indolence or impotence rather than tolerance.

He knows that what he calls vermin are troublesome if not injurious. He protects himself and what he considers his property against them more or less consistently and completely; but in proportion to their power to evolve helpfully in harmony with conditions of life in the chinks and crannies of the world into which he can not or does not follow them, they escape and thrive not only despite him but at his expense and literally on him. The rat is his uninvited guest the world over, and the gray rat, if he were worshipful and learned, would render daily thanks to the patron who has made him the rat of rats, transporting, housing and feeding him to an almost unbelievable extent. Rust, smut, mildew, and fermentative germ thrive under his régime; the world population of codling moth and chinch bug has enlarged a myriadfold through the ability of these self-seeking creatures to get forward as riders on man's own self-seeking progress.

Perhaps in this survival and increase of parasites and other vermin lies the token that

the earth and the fulness thereof are not to man; for if the Nature whose product he is permits his enemies to thrive and multiply notwithstanding his effort to protect himself, she gives in this permission a strong suggestion that his power is only an expression of her own power, and that while he sleeps and relaxes effort her activity continues unabated along the line of peopling the earth toward its full capacity with a million forms of creatures to each one of which she offers the same fundamental problem as his own—perpetuation of the individual and of its kind, or restriction and disappearance, according to its fitness and adaptability under the conditions of the moment.

We owe the privilege of wearing the key of the Sigma Xi to the fact that at some time or other each one of us has been recognized by investigators as something of a zealot in their own field, giving promise or bearing the first fruits of his own investigation. In our turn, we welcome to companionship the brothers of a newer day.

Most of us enter this fellowship from the novitiate of university life under guidance and supervision. The founders of the society, themselves, had achieved in college or professional school the qualifications that they prescribe for membership. Their forerunners in investigation through the centuries, for the most part had traveled the same route. Our organization is represented in laboratories rather than in the halls of classic learning.

Those of us who have been connected with the society very long have no difficulty in calling to mind a number of men of our own or an earlier or a later generation, whose lot has not been cast in with the university or the college, but who in purposeful prying into science have shown the zeal that our society stimulates and who in productive and stimulating accomplishments may have surpassed us of seemingly greater opportunity. Those who initiated the inquiry into nature out of which such enormous knowledge and utility have poured into the lives of men within the last few generations, trained themselves or founded the schools in which others have been trained. Their zeal and industry and wisdom were the attributes of the highest human mentality: often, but unfortunately not always, infectious; exceptionally, and this happily, of such quality as to confer immunization on those who came into closest contact with them.

Like other forms of human social development, the specialization of investigators offers many parallels to the specialization of organs and of organisms in nature. Its beginnings were very individualistic and sporadic. Its spread was limited by the natural barriers of sea and mountain, and the quite human obstacles of differing race and language. Investigation usually has meant not a road leading to a successful career—as the animal success of man is measured, but a bypath more often leading to poverty and misunderstanding, and usually at best a way that could not be traveled safely very far from the beaten path of approved and utilized learning. My own university mentor, Farlow, like his great leader, Asa Gray, studied in the practical field of medicine so that he might be assured of the privilege of wandering—nobody could tell how far—into investigation apart from its immediate application in a necessary art.

No doubt it is true that to some investigators the thought that no practical application could be made of their discoveries has lent added fascination to their work. No doubt to others an investigation undertaken with the purpose of securing the answer to an economic question still lacks in attractiveness. The greatest incentive to such work has been an innate thirst for knowledge for its own sake and a love of its pursuit.

Even with the multiplication and broadening and deepening of universities that the last generation has witnessed, the privilege of adding to knowledge, of shaping something up by one's own effort, has resided very largely in the opportunity offered by a university chair for stealing a little time and a little effort from the first and paramount duty of the professor, teaching what is known already and training adaptable minds to meet life's needs.

Even to-day and among our own friends are to be found men who fail to see that the university that we know not only watches with some care over teaching schedules so that the man who wishes to follow productive lines in his scholarship may not find that he has no time left for this after completing his prescribed task as a teacher, and who fail to comprehend that one is misplaced in a true university if he can merely retail what others have made known.

As yet, most of us who have been judged worthy of membership in the society of the Sigma Xi have acquired our status as investigators as a byproduct of our opportunity as teachers; for what are called research professors are few and far between, and organizations for investigation only are none too common. We find encouragement in the stimulating fraternal association. We touch at a tangent the productive activities of colleagues in our own department or in related departments. We lay our little offerings before local or state or national gathering of our confreres, and come home with suggestions for bettering and amplifying our own activities. We get what we may out of an undigested and heterogeneous program, and give little thought to the assimilability in it of what we contribute to it.

We are individualistic to a surprisingly large degree. As a rule we are generous to a fault with what we have to offer to others and as a rule we are not greedy in seizing on such help as they offer to give to us; above all we are not markedly seekers after advice or direction. We enjoy the prerogatives of the present, but cling to the methods of the past.

From the time when learning awoke after the world's long sleep, when civilization began really to have meaning outside of very restricted circles, the occupation that has become our profession has resembled my Antillean century plants in following its inherent bent. The conditions of its environment have presented an increasingly harmonious optimum for its simple existence, with neither serious competition nor any great obstacle interposed anywhere to its drift along the lines of least resistance—or in this case of greatest attractiveness. That conditions have changed is evident enough, but they have changed gradually and the changes have been in favoring directions.

The aggregate utility of what is called research had led, even, to its sedulous cultivation in a limited way: but even under cultivation it has shown few mutations unfitting it for continued existence if once more thrown over to the unrestricted action of natural selection. It has scarcely become domesticated. Its survival and increase have been of the fit rather than of the fittest, where change about us has been gradual and of degree rather than of kind, and where neglect rather than encouragement have favored it. It has resembled the wayside weed doing too little harm to be worth repression, and more or less useful for fodder or bedding-down when the trouble was taken to harvest its produce.

Almost suddenly we are confronted with totally different environing conditions. The last decade has seen an interest in scientific investigation that was unknown before. The period of the war has brought its real value to recognition. The harmless weed has been seized on as most promising for intensive cultivation. Its natural attributes are being selected and blended with a skill such as the agriculturist uses in bettering his crops and his stock. Its maximum development is favored by a more or less serious effort to remove or reduce disturbing competitors. The stigma that science, the organizer of knowledge, has not organized itself seems about to be removed.

"Tempora mutantur, et nos, in illis." The almost catastrophic changes that the last few years have brought into the human world is placing scientific research on a business basis. It is not too much to expect great things from its effective organization as a means to an end: or to expect it to yield quickly in orderly controlled team play results that individual fatuous effort could bring about slowly and disconnectedly if at all.

Is science capable of transplantation and cultivation under artificial conditions? If so, the product will differ from the original in kind as well as in degree quite as much as the highly specialized animals and plants of the farm do from their undomesticated prototypes. If so, its nature will have shown a plasticity to be looked for in nature hardly elsewhere than in the outgrowth of human intelligence.

Transplantation is actually at work. The investigating manpower of the world is being registered with startling rapidity, preliminary to preferred enrollment or selective conscription. There is scarcely a person here present who will not feel its force within a few years if the signs of the times are to be trusted. To the organizer, it promises new and enlarged opportunity for leadership. To the drudge it holds opportunity for the kind of shoulder-to-shoulder effort before which mountains crumble and the bowels of the earth yield up their secrets; but the drudge by birth is a rara avis among men moved by the real spirit of investigation, and the drudge from necessity is neither a happy nor always a profitable artefact.

That the new order will survive is almost certain. That its survival will be through artificial rather than natural selection is probable. That it will be a survival of the unlike is self-evident.

That waifs and escapes from it will be found outside the cultivated fields is to be expected. Whether these shall profit the gleaner like strays of wheat, or foul the fleece like the carrots of the roadside, or prove all but baneful like the reverting parsnip, remains to be proved. In any event, if not destroyed, they may be counted on through the centuries to furnish vestiges of the old and primitive stock as rudiments for a new start when, if ever, the cultivation of research is abandoned—provided that the present cultivation is not so intensive as to destroy them utterly.

In the primitive desultory gratification of human interest in human environment lies the essence of investigation for investigation's own sake. The amateur in science has entered, occupied uncontested the center, and is passing from the scene.

The largest creel of fish may be secured by seining or dynamiting or drugging the pool; and the largest bag of birds, by the skilful use of a net on a drizzly day. The market, unless glutted, will pay for the haul. But the sportsman does not wish to become a pot-hunter, and the naturalist knows that game must be protected to a reasonable extent if fishing and hunting are to continue and if sportsmanship is to endure. Forest and mine are most attractively exploited by organized onslaughts that take what it pays to take and sometimes leave a wake of destruction behind. The profit of the day is great, the rapid material progress to which it contributes is held to justify the attack: but what of the future?

Organization of attacks on the secrets of nature differ from organization of attacks on the material products of nature in this very essential respect, that the former do not destroy but rather bring the world's material resources to more effective and economic utilization. But is such purposeful organization likely to hamper or put an end to unorganized though purposeful and intelligent investigation? Is the seiner likely to foul the pool or barricade it against the sportsman?

Organization backed by a probable profit and loss sheet and a program for each enterprise—once called a proposition, and now a project—enlists capital in business. Such organization and reinforcement are enlisting already, for research, capital looking to ultimate return, and also impersonal endowment because of the established repute of science as conducing to the general welfare of man.

To the investigator, investigation may become a renumerative profession when he bears his alloted share in cooperative effort. For the most part, up to the present he has paid amply for the privilege of doing such work; and to enjoy the privilege of doing it even on these terms he has rather gratefully if sometimes complainingly sold his services

as a teacher at a ridiculously low figure when measured by his training and talent.

He has done and is doing this under the spur of that most intangible but most essential trait of man that we call character, and because of those chimæras of the mind of man that we call ideals. Is he sanely enough balanced to conform his ideals to the trend of the times, to the chance for subordinating them to the broader plans of leadership; or are ideals never ideals when his own mind does not shape them, when from sport—which one pays for, they become work—for which one is paid? And if the zealot who can not modify his view still continues in our midst, as he must, is he to be weeded out; or allowed on sufferance to occupy the waste places of research; or to be kept purposefully from extermination, against a day when the nourishing hand of society may be withdrawn, and zeal in research again becomes synonymous with its primal meaning—devotion with all one's character to one's inborn ideal?

As we, the professionals in science who follow the amateur on to the stage, find ourselves marshalled in the ranks or leading the artisans of science, it may be well to remember that a Galileo, a Newton, a Berzelius and a Darwin lived and worked—not in vain—before the day of organization and intensive team work had dawned!

WILLIAM TRELEASE
THE UNIVERSITY OF ILLINOIS

THE STRUCTURE OF THE HELIUM ATOM

ACCCORDING to the model which Bohr proposed in 1913, the helium atom consists of two electrons moving in a single circular orbit having the nucleus at its center. The electrons remain at the opposite ends of a diameter and thus rotate in the same direction about the nucleus. The angular momentum of each electron is assumed to be $h/2\pi$, where h is the quantum constant. The ionizing potential of helium calculated by this theory is 28.8 volts. Recent experimental determinations by Franck and Knipping have given 25.4 ± 0.25 volts. Bohr's theory is approximately right but does not give the true structure.

For the hydrogen atom and helium ion, atoms containing but a single electron, Bohr's theory seems to be rigorously correct. For atoms containing more than one electron there are many facts which indicate that modifications or extensions are needed.

The chemical properties of the elements, particularly the periodic relationships and the phenomena of valence, have shown definitely that the electrons are not in general arranged in coplanar orbits. According to the theory which I advanced last year, the electrons in their most stable arrangements move only within certain limited regions about the nucleus, each of these cells containing not more than two electrons. The atoms of the inert gases were found to have their cells arranged symmetrically with respect to an equatorial plane, no electrons however ever lying in this plane. According to this view, the two electrons in the helium atom should not move in the same orbit but in separate orbits symmetrically located with respect to the equatorial plane. The two electrons in the hydrogen molecule (and in every pair of electrons which acts as a chemical bond between atoms) must be related to one another in the same way as those of the helium atom.

The most obvious model of this type is one in which the two electrons move in two circular orbits in parallel planes equidistant from the nucleus. By properly choosing the diameters of the orbits, the force of repulsion between the electrons is compensated by the component of the attractive force of the nucleus perpendicular to the plane. This model however proves impossible as it gives a negative value (— 5.8 volts) for the ionizing potential.

A. Landé[1] has recently proposed a model for the eight electrons of an octet in which each electron occupies a cell bounded by octants of a spherical surface. The eight electrons move in such a way that their positions are symmetrically placed with re-

[1] *Verh. d. phys. Ges.*, 21, 653, October, 1919.

spect to three mutually perpendicular planes which pass through the nucleus. When one electron approaches one of these planes it is retarded by the repulsion of the electron on the other side of the plane and is thus prevented from passing through the plane. Although each electron remains within a given octant of the spherical region about the nucleus, yet the momentum of the electron is transferred to the electrons in adjacent cells across the cell boundaries. In this model the momentum travels continuously around the atom in a circular path, being relayed from electron to electron. Thus even though the electrons do not leave their respective cells, the mathematical equations for their motion are very closely related to those which apply to the motions of electrons in circular orbits about the nucleus. Landé's calculations lead to the conclusions that this type of motion is less stable than one in which all eight electrons move in a single plane orbit. This objection can be overcome if we assume that the angular momentum of each electron is $h/2\pi$ instead of the double value which is usually assumed for the electrons in the second shell. In fact, this conception gives grounds for believing that all electrons in their most stable positions in atoms, have orbits corresponding to single quanta and it is only because we have assumed coplanar orbits that we have been led to the conclusion that the outer orbits correspond to increasing numbers of quanta.

This model of Landé's has suggested to me that there should be a similar interrelationship between the two electrons of the helium atom, and also of the hydrogen molecule, and of the pair of electrons constituting the chemical bond.

I assume that the two electrons have no velocity components perpendicular to the plane which passes through the nucleus and the two electrons. The motion is thus confined to a single plane. The two electrons, however, are assumed to rotate about the nucleus in *opposite* directions, and in such a way they are always located symmetrically with respect to a line passing through the nucleus. Consider for example that this line of symmetry is horizontal and that one electron is located directly above the nucleus at a unit distance, and is moving horizontally to the right. Then the other electron will be located at an equal distance below the nucleus and will move in the same direction and with the same velocity. If there were no forces of repulsion between the two electrons, and if we choose the proper velocities, it is clear that the two electrons might move in a single circular orbit about the nucleus, but in opposite directions of rotation. This would require, however, that the electrons should pass through each other twice in each complete revolution. When we take into account the mutual repulsion of the electrons, we see that their initial velocities will suffice to carry them only within a certain distance of each other, and they will then tend to return in the general direction from which they came. With properly chosen initial conditions the electrons will return back exactly on the paths in which they advanced and will then pass over (towards the left) to the other side of the nucleus and complete the second half of an oscillation. Each electron has its own orbit which never crosses the line of symmetry. The orbit however does not consist of a closed curve, but a curved line of finite length along which the electron oscillates.

Unfortunately the equations of motion for this three-body problem are difficult to handle and I have only been able to determine the motion by laborious numerical calculations involving a series of approximations. These however, can be carried to any desired degree of accuracy. By four approximations I have been able to calculate the path and the velocities, etc., to within about one tenth per cent. It is to be hoped that a general solution of this special type of three-body problem may be worked out, if indeed one is not already known to those more familar with this type of problem.

The results of this calculation show that the path of each electron is very nearly an arc of an eccentric circle, extending 77° 58′ each

way from the mid-point (as measured from the nucleus). If we take the radius vector at the mid-point to be unity then the radius at the end of the arc is 1.138. The angular velocity of the electron at the mid-point of the path is such that if it continued with this velocity it would travel through 105° 23′ during the time that it actually takes to move to the end of its orbit (*i. e.*, through 77° 58′).

By imposing the quantum condition that the angular momentum of each electron at the mid-point of its path shall be $h/2\pi$, it becomes possible to calculate the radius vector and the velocity in absolute units. The radius vector for the electron at its mid-point is 0.2534×10^{-8} cm. which is 0.8359 of the radius of the orbit of Bohr's model (0.3031×10^{-8} cm.). Even at the end of the orbit the radius (0.2882×10^{-8} cm.) is less than that of the Bohr model. The angular velocity at the mid-point is 1.431 times that of electrons of the Bohr atom. The number of complete oscillations per second is 24.63×10^{15}, which is 1.222 times as great as the number of revolutions in the Bohr atom (20.16×10^{15} per second). The total energy (kinetic plus potential) of the oscillating atom is 0.9615 of that of the Bohr atom. The ionizing potential of helium according to the new model should be 25.59 volts which agrees with Franck and Knipping's experimental determination within the limits of error given by them, but differs from the 28.8 volts given by Bohr's theory by nearly ten times the experimental error.

The oscillating model is thus not only satisfactory from a chemical point of view but is in quantitative agreement with the properties of helium. The fact that there can be no corresponding structure with three electrons is in accord with the fact that lithium (which has three electrons) is an element having totally different properties from helium.

The calculation for the hydrogen molecule involves greater difficulties. Bohr's model with the two electrons moving in a single circular orbit gives a heat of dissociation of about 63,000 calories, whereas experiment gives about 90,000. The calculations for helium have shown that the radius of the oscillating atom is considerably smaller than that of the Bohr atom, so that the force of attraction between the electrons and the nucleus is much (20 per cent. or more) greater. In the hydrogen molecule this increased force may result in drawing the two nuclei closer together thus increasing the stability of the molecule. Calculations of the orbits of the electrons in the hydrogen molecule are in progress.

The final results with a description of the methods of calculation will be published probably in the *Physical Review* and the *Journal of the American Chemical Society*.

IRVING LANGMUIR
RESEARCH LABORATORY OF THE
GENERAL ELECTRIC COMPANY,
SCHENECTADY, N. Y.,
June 5, 1920

ALFRED WERNER[1]

ALFRED WERNER, professor of chemistry in the University of Zurich, died on November 15, 1919, at Zurich, Switzerland.

Professor Werner was elected an honorary member of the American Chemical Society at the general meeting held in New Orleans, La., April 1, 1915. It is now desired to leave upon the permanent records of this society a tribute to his genius and indomitable energy, and to the wealth of the contributions which he made to our science.

Born at Mulhausen in Alsace on December 12, 1866, he was educated at the technical schools of Mulhausen, Karlsruhe, and Zurich. Later he studied with Berthelot at Paris.

His first published work of note was upon the stereoisomerism of organic compounds containing nitrogen. Applying these theories to the unclassified mass of complex inorganic ammonia compounds, he realized the inadequacy of accepted ideas of valence to explain their constitution. Largely from a study of isomers among these complexes, whose consti-

[1] Tribute prepared by a committee of the American Chemical Society consisting of C. H. Herty, H. L. Wells and Arthur B. Lamb.

tution could be explained only on a basis of stereoisomerism, he developed an extension of the valence hypothesis and introduced the concept "coordination number" of elements.

This conception was the stimulating cause of a great mass of researches which embodied the discovery of many new compounds, many new examples of isomerism, brought rational classification into the whole field of complex inorganic compounds and led by logical development of theoretical views to the discovery of optically active inorganic compounds. None realized more clearly than he that in his extension of the valence hypothesis he had not reached any ultimate truth but had merely added one definite stepping stone.

To the little laboratory in Zurich, with its all too limited equipment, he attracted students from every part of the world. Eventually adequate funds were placed at his disposal, with which was constructed one of the model laboratories of Europe. His fear at the time was that he might not be able to carry into the commodious new quarters the spirit which had permeated the old laboratory. This fear was groundless, as the character of the researches from the new laboratory abundantly proved.

In 1912 Professor Werner was LeBlanc Medallist of the Société Chemique de France. In 1915 he was elected an honorary member of the Chemical Society (London) and in the same year was awarded the Nobel Prize in Chemistry.

An indefatigable seeker after truth has gone to his rest. The example of his life remains a constant inspiration.

SCIENTIFIC EVENTS

THE UNITED STATES COAST AND GEODETIC SURVEY AND RECENT CONGRESSIONAL LEGISLATION

During the past session of Congress, the U. S. Coast and Geodetic Survey was benefited by provisions in three bills.

In the act making appropriations for the naval service for the fiscal year ending June 30, 1921, it is provided "That the superintendent of the Coast and Geodetic Survey shall have the relative rank, pay and emoluments of a captain in the navy, and that hereafter he shall be appointed by the president, by and with the consent of the senate, from the list of commissioned officers of the Coast and Geodetic Survey not below the relative rank of commander for a term of four years, and he may be reappointed for further periods of four years each.

In the act making appropriations for the sundry civil expenses of the government for the fiscal year ending June 30, 1921, it is provided "That the title of 'superintendent' of the United States Coast and Geodetic Survey is hereby changed to 'director,' but this change shall not affect the status of the present incumbent or require his reappointment, provided further that the secretary of commerce may designate one of the hydrographic and geodetic engineers to act as assistant director."

The third act which contains legislation affecting the commissioned personnel of the Coast and Geodetic Survey is one entitled, "An act to increase the efficiency of the commissioned and enlisted personnel of the Army, Navy, Marine Corps, Coast Guard, Coast and Geodetic Survey, and the Public Health Service, through the temporary provision of bonuses or increased compensation." This act provides for certain increases in salary for all commissioned officers varying in amount from $480 to $840 per annum. It contains the following provision affecting the commissioned force of the Coast and Geodetic Survey:

> That in lieu of compensation now prescribed by law, commissioned officers of the Coast and Geodetic Survey shall receive the same pay and allowances as now are or hereafter may be prescribed for officers of the Navy with whom they hold relative rank as prescribed in the act of May 22, 1917, entitled, "An act to temporarily increase the commissioned and warrant and enlisted strength of the Navy and Marine Corps, and for other purposes," including longevity; and all laws relating to the retirement of commissioned officers of the Navy shall hereafter apply to commissioned officers of the Coast and Geodetic Survey; *Provided*, That hereafter longevity pay for officers in the Army,

Navy, Marine Corps, Coast Guard, Public Health Service and Coast and Geodetic Survey shall be based on the total of all service in any or all of said services.

This law makes a substantial increase in the pay and allowances of the commissioned personnel of the Coast and Geodetic Survey who hold relative rank from second lieutenant to colonel in the army and from ensign to captain in the navy. The commissioned personnnel of the Surveys will also be greatly benefited by the retirement clause of this act. The salary scale for the commissioned personnel of the survey had previously been so inadequate that it was impossible to secure applicants for the vacant positions. This is shown by the fact that there are to-day about 40 vacancies in the commissioned force of 140. This has been increased to 50 by the retirement of ten officers who have reached the retirement age. In the future the pay and allowances of the lowest commissioned grade will be about $2,500 per annum. Appointments to this grade will be made from the grades of junior engineer and deck officer, the entrance positions. Six months' experience in the lowest grade is necessary before promotion to the commissioned personnel.

The U. S. Civil Service Commission will shortly announce an examination to be held about the middle of July from which to secure eligibles to fill the entering positions.

THE ROCKEFELLER FOUNDATIONS ENDOWMENT OF UNIVERSITY COLLEGE, LONDON

THE Rockefeller Foundation has offered to give about $6,000,000 to University College, London, and its hospital. Dr. George E. Vincent has issued a statement in which he says:

Since the Rockefeller Foundation is cooperating with governments in many parts of the British Empire it recognizes the importance of aiding medical education in London, where the training of personnel and the setting of standards for health work throughout the empire are so largely centered.

The University College and Hospital School have been selected because of the physical unity of the hospital and medical school buildings and the close relationships existing between the University College, which provides the laboratory courses, and the University College Hospital and Medical School, which furnishes clinical teaching.

The college and school are fortunate in having assembled a group of able men who are deeply interested in teaching and research. E. H. Starling and William M. Bayliss, physiologists, and G. Elliot Smith, anatomist, are scientists of distinction, while T. R. Elliott, G. Blanker Thomas Lewis, Sir John Bradford, C. C. Choyce, H. R. Kenwood, H. Betty Shaw and Sydney Martin are clinicians of recognized standing.

The authorities of the schools, supported heartily by the faculty, have organized full-time clinical "units" in such a way as to combine the care of patients and research with the teaching of students. This feature of the work especially influenced the foundation to decide to assist in furthering a plan which it is believed will have an important effect upon the development of British medicine.

The building program for which £590,000 have been appropriated will include an institute of anatomy comparable with any in the United States. A new home for nurses, new quarters for resident physicians, a biochemical building, laboratory facilities in close connection with hospital wards, the remodeling of a hospital with the addition of twenty beds, and a new obstetrical unit with a capacity of sixty patients. These additions will provide a total of 500 beds.

It is proposed to increase the annual expenditures by the approximately £50,000, of which the foundation will provide endowment to produce an income of £30,000. This additional maintenance will be expended upon a new staff in anatomy, an increase in the staff of physiology, the provision of a full-time unit in obstetrics and various items of increased laboratory and clinical service throughout the institutions concerned. It is believed that the obstetrical unit plan offers prospects of a success which will be of value to the entire world. The subject now in England, as elsewhere, is poorly taught and needs reorganization under improved conditions.

The foundation has a special interest in the proposed Institute of Anatomy because thus far under British auspices a true university department which combines both teachings and research in the fields of anatomy, histology and embryology has not been developed. It is believed that such an institute, by unified efforts in these three branches of anat-

omy, is of prime importance not only to the teaching of the medical student but also for the progress of anatomy, particularly on its research side.

GIFTS TO UNIVERSITIES AND COLLEGES

Trustees of the General Education Board and of the Rockefeller Foundation announce appropriations of $20,251,900 for various purposes of general education and for the development of medical schools. The statement of the trustees is as follows:

For appropriations from the fund of $50,000,000 which Mr. Rockefeller gave last December nearly 250 institutions have made application to the General Education Board. A careful statistical inquiry shows that in order to raise the level of salaries in a sufficiently large number of these institutions, to a degree somewhat commensurate with increased cost of living, their endowment funds would have to be increased by from $150,000,000 to $200,000,000.

It is evident that to accomplish this result the $50,000,000 in the hands of the board will have to be supplemented by funds from other sources in the ratio of two or three to one. This has been kept in mind in making appropriations which have been made contingent upon the raising of additional amounts.

At the recent meeting appropriations were made to ninety-eight colleges and universities out of those which are under consideration. To this group of institutions the General Education Board appropriated for endowment to increase salaries the sum of $12,851,666 on condition that they would themselves reach the goal they had set and secure for the same purpose supplementary sums aggregating $30,613,334. Thus, these colleges and universities if successful will increase their endowments available for teachers' salaries to the extent of $43,465,000.

In a few cases institutions are not asking for endowment funds but only for temporary contributions toward a certain total annual subscription which it is hoped later to fund permanently. The board has made a number of such appropriations on a two- or three-year basis.

For these purposes an additional sum of $2,184,384 was appropriated covering a period of one to three years, making a total appropriation by the general education board from Mr. Rockefeller's special gift of $15,036,050.

In the following list appropriations to medical schools in the United States were made by the General Education Board, while those to institutions in Brussels and Halifax were voted by the Rockefeller Foundation.

Washington University Medical School, St. Louis—For endowment, $1,250,000; for additional laboratory facilities and equipment, $70,000.

Yale Medical School—For endowment (toward a total of $3,000,000), $1,000,000.

Harvard Medical School—For improved facilities in obstetrics, $300,000; for the development of teaching in psychiatry, $350,000.

Johns Hopkins Medical School—For development of a new department of pathology (toward a total of $600,000) $40,000.

Dalhousie University Medical School, Halifax—For buildings and equipment, $400,000. For endowments, $100,000.

Medical Research Foundation of Elizabeth, Queen of the Belgians, Brussels—For general purposes of medical research, 1,000,000 francs.

ENDOWMENT OF THE MEDICAL SCHOOL OF THE UNIVERSITY OF ROCHESTER

Mr. George Eastman and the General Education Board have given the University of Rochester $9,000,000 for a school of medicine, surgery and dentistry. In connection with it the Rochester Dental Dispensary, an institution recently built and endowed by Mr. Eastman, will furnish the clinic for the study of dentistry, at the same time continuing its present work in caring for the teeth of children. The details of the endowment were announced at Rochester on June 12, by Dr. Rush Rhees, president of the university; Dr. Abraham Flexner, secretary of the General Education Board, and Mr. Eastman, head of the Kodak industry, at a meeting of the trustees of the university, dispensary and local hospitals and other persons directly interested. Of the $9,000,000 the General Education Board gives $5,000,000 and Mr. Eastman $4,000,000. This is in addition to the dispensary which with its endowment is valued at $1,500,000. The most modern laboratories for anatomy, physiology and pathology and a 250-bed teaching hospital are to be constructed.

SCIENTIFIC NOTES AND NEWS

NEW YORK UNIVERSITY has conferred the doctorate of laws on Dr. William H. Nichols, president of the General Chemical Company of New York, and recently president of the American Chemical Society.

THE University of Maine has conferred the Ph.D. on Dr. Lamson Scribner, of the United States Department of Agriculture.

THE University of Arizona has conferred the degree of doctor of laws on Thomas Henry Kearney, of the U. S. Department of Agriculture, in recognition of his work in the breeding of Egyptian long-staple cotton at the Sacaton Station in Arizona. Here he and his co-laborers isolated the first plant of the Pima variety of cotton, so well adapted to the southwestern region, propagated it to the extent necessary to make commercial plantings, and are still occupied in producing a large amount of absolutely pure seed each year. The Pima cotton crop of Arizona was worth approximately $20,000,000 in 1919.

THE honorary degree of doctor of science was conferred upon George N. Hoffer, of the U. S. Department of Agriculture, by Lebanon Valley College, at their fifty-fourth annual commencement exercises, in recognition of his contribution to our knowledge of cereal diseases. Dr. Hoffer graduated from Lebanon Valley in 1909 and is at present working at the experiment station at Purdue University.

DURING a visit to Millbank Hospital on June 8, King George bestowed on Major General William C. Gorgas, former surgeon general of the United States army, the insignia of Knight Commander of the Order of St. Michael and St. George. General Gorgas was a patient in Queen Alexandra's Nursing Home for Officers.

THE president of the French republic has conferred the honor of Officer of the Legion of Honor on Dr. Aldo Castellani, of the London School of Tropical Medicine, for his method of combined typhoid-paratyphoid and enteric-cholera vaccination.

AT the end of the present academic year Professor Frederic S. Lee retires, at his own request, from the directorship of the department of physiology of Columbia University, and hereafter he will occupy a research professorship. He sails for Europe early in July and expects to spend the coming year abroad.

MR. G. W. MOREY, of the Geophysical Laboratory, Carnegie Institution of Washington, who has been on leave of absence and in charge of the optical glass plant of the Spencer Lens Company of Buffalo, New York, since November, 1918, has returned to resume his research work at the laboratory.

PROFESSOR CHARLES BASKERVILLE, in recognition of his investigations on inhalation anesthetics, has been elected a member of the research committee of the National Anesthesia Research Society.

AT the St. Louis meeting of the American Chemical Society a communication was presented from Dr. W. F. Hillebrand regarding the apparently organized thefts of platinum ware that are taking place throughout the United States, with the suggestion that a committee be appointed to consider whether or not legislation might not be recommended to Congress which would assist in controlling the matter. The council voted that such a committee be appointed, and the president appointed R. B. Moore, of the Bureau of Mines, Washington, D. C., Chas. H. Kerk, of J. F. Bishop & Company, Malvern, Pa., and Geo. F. Kunz, of Tiffany & Company.

SIR HUMPHREY D. ROLLESTON, Royal College of Physicians of London; Colonel H. J. Waring, Royal College of Surgeons of London; Dr. Norman Walker, Royal College of Physicians and Royal College of Surgeons of Edinburg and the Royal Faculty of Medicine and Surgery of Glasgow, and Professors Gustave Roussy and E. E. Desmarest, of the University of Paris, were present at the meeting of the American Medical Association at New Orleans and have been visiting the leading medical centers of the country. They are the guests of the National Board of Medical Examiners of the United States.

DR. W. C. PHALEN, formerly geologist in the U. S. Geological Survey and mineral technol-

ogist in the Bureau of Mines, has been engaged as geologist by the Solvay Process Company with headquarters at Syracuse, N. Y.

A meeting of the New York Section of the Société de Chimie Industrielle was held at Rumford Hall, on the evening of May 14. The following officers were elected: *President,* Marston T. Bogert; *Vice-president,* J. Enrique Zanetti; *Treasurer,* J. V. N. Dorr; *Secretary,* Charles A. Doremus; *Council,* Jerome Alexander, L. H. Baekeland, Charles Baskerville, Henri Blum, Charles F. Chandler, René Engel, Georges de Geofroy, Ellwood Hendrick, Charles H. Herty, George F. Kunz, W. H. Nichols, G. E. Valabrègue. The meeting was addressed by M. Maurice Casenave, minister plenipotentiary, director-general of French Services in the United States on "Commercial relations between France and the United States," and by Mr. Joseph H. Choate, general counsel of the Chemical Foundation, Inc., on "Conditions of the chemical industry in the United States before the war."

Dr. L. Hektoen, of the John McCormick Institute for Infectious Diseases, Chicago, delivered the Noble Wiley Jones lectures of the University of Oregon, on May 31 and June 2, the subject of the first lecture being "Old and new knowledge of humidity" and of the second "Phases of streptococcus infection."

Dr. W. Van Bemmelen, director of the Magnetic and Meteorological Observatory of Batavia, delivered an address on "The volcanoes of Java," before the Washington Academy of Sciences on June 15.

On May 24, 1920, a statue of Edward Van Beneden was unveiled at Liège, Belgium, with appropriate exercises. Dr. Robert W. Hegner, of the school of hygiene and public health of the Johns Hopkins University, acted as the American representative on this occasion.

In the issue of Science of April 23 it was stated that the family of Mr. Henry Phipps had given $500,000 to the Henry Phipps Institute of the University of Pennsylvania for the study of tuberculosis. We are requested to state that this sum is given contingent on the raising of a total of $3,000,000 for the endowment of the institute.

Dr. J. Lunell, physician and botanist at Leeds, N. D., since 1894, has died. Dr. Lunell was an enthusiastic botanist and published a number of articles on North Dakota plants, the most extensive of these is the Catalogue of the Vascular Plants which was noted in this journal for November 1, 1918.

The tenth season of the Marine Laboratory of Pomona College will begin June 24, at Laguna Beach, Orange county, California. There will be several courses in general biology and general zoology. There are opportunities for special work, and eight private laboratories are reserved for investigators.

The publication committee of the Zoological Society, London, has issued a notice calling the attention of those who propose to offer papers to the great increase in the cost of paper and printing. This, it is stated, will render it necessary for the present that papers should be condensed, and be limited so far as possible to the description of new results.

Dr. Cornelius Betten, for the past five years secretary of the New York State College of Agriculture, has just been made vice-dean of resident instruction, the appointment to take effect July 1, 1920. Dr. Betten is a graduate of Cornell, of the class of 1906, where he was fellow in entomology. After graduation he went to Lake Forest College at Lake Forest, Illinois, where he was professor of biology and head of the department. In 1915, he returned to his alma mater as secretary of the college of agriculture. Under authorization of recent legislation for the college of agriculture, provision is made for three vice-deans or directors; a vice-dean of the college, a vice-director of extension, and a vice-director of the experiment station. The faculty of the college was asked to make nominations, and Dr. Betten was practically selected by his associates, the actual appointment by the trustees of the university being a ratification of the faculty's choice. Professor M. C. Burritt has been for some time vice-director of extension. The vice-director of experiment stations still remains to be chosen. Under

the present plan, Dean A. R. Mann has the aid of three vice-officers as executives in the three main branches of the work of the college; resident instruction, extension, and research.

THE geological department of the New York State Museum will send into the field this year a considerable corps of workers for the purpose of collecting the fossil terrestrial plants of the Devonian Period. The collections of the museum are already very rich in such plant material, but it has all been acquired incidentally to the study of the fossil faunas of the state, and the reports of the museum have given inadequate attention to this important field. The physical conditions under which the Late Devonian deposits were laid down in New York were distinctly favorable to the accumulation of terrestrial plants in the shallow water offshore sands and shales, and it was said by Sir William Dawson that the state museum possessed a more extensive representation of this early land flora than was to be found elsewhere. The standing tree ferns found many years ago in the sands of Schoharie county and which are exhibited in the museum, are the oldest representatives of a terrestrial forest growing in place; the unique Archeosigillaria, 18 feet in length, is another extraordinary plant from this flora and these striking objects, supplemented by much unstudied material, give promise that the field may be opened to a more adequate knowledge of the first great land flora of the earth.

UNIVERSITY AND EDUCATIONAL NEWS

DR. FREDERICK CHARLES HICKS, Sinton professor of economics, has been elected president of the University of Cincinnati, succeeding Dr. Charles W. Dabney, who retires on reaching the age of sixty-five. Dr. Hicks went to the University of Cincinnati in 1900 as head of the department of economics, having previously taught in the University of Michigan and the University of Missouri.

MR. HOMER P. LATIMER, professor of anatomy at the University of Nebraska, has been granted leave of absence for the year 1920–21. He will spend this summer and next year in study at the Institute of Anatomy of the University of Minnesota. Mr. D. S. Brazda has been appointed instructor in anatomy to take charge of some of the classes during Professor Latimer's absence.

PROFESSOR S. ELIZABETH VON DUYNE, M.D., resident physician and professor of physiology and hygiene at Converse College, has resigned to accept a similar position at Goucher College, her alma mater.

DR. LINUS W. KLINE, formerly professor of psychology and education in the Duluth Normal School, who has been engaged in research at the Johns Hopkins University during the past year, has been appointed professor of psychology and education in Skidmore College.

DR. P. W. WHITING, in charge of biology at Franklin and Marshall College, Lancaster, Pa., has resigned to accept a position at St. Stephens' College, Annandale-on-Hudson, New York.

DR. RICHARD J. HARDING, McGill University, has been appointed professor of chemical pathology in the University of Toronto by the board of governors of the university.

DISCUSSION AND CORRESPONDENCE

SCIENTIFIC WORK IN THE HAWAIIAN ISLANDS

HAVING recently returned from a tour of the Hawaiian Islands, and having familiarized myself with the scientific work that is being done there and which remains to be done in the Islands to the south, I am particularly interested in the success of the Congress so ably planned by Professor Herbert E. Gregory, of Yale University, who is now resident in Honolulu as director of the Bernice Pauahi Bishop Museum.

While the problems presented by the Islands are chiefly in geology, volcanology, and anthropology, there is also a great deal of interest in various fields of zoology and oceanography.

The cooperation planned by Professor

Gregory is designed to extend to the scientific men of New Zealand and Australia, and to take into consideration the larger work of the future, particularly as suggested by the vanishing anthropology of Polynesia. Unless this work is begun immediately and carried through with great energy and system, it will not be done at all. The material in physical anthropology is disappearing with almost incredible rapidity. The ravages of influenza during the past two years have swept away a large part of the members of the Polynesian race. The survivors on certain of the Islands constitute a very small percentage of the original population.

Scientific cooperation has begun through the special research in physical anthropology of the Hawaiian group established between the Bishop Museum and the American Museum of Natural History. Dr. Louis R. Sullivan of the American Museum staff has already left for the Islands and will make as complete a survey as possible of the pure and mixed Hawaiian races among the remnants. These results will be published in the *Memoirs* of the Bishop Museum. It is expected also that Curator Clark Wissler will represent the American Museum at the Pan-Pacific Scientific Congress in August.

Henry Fairfield Osborn

THE ENERGY OF SMALL OSCILLATIONS

To the Editor of Science: The well-known theorem that in any linear harmonic oscillation the total energy is, on the average, half kinetic and half potential is so important in many fields that perhaps the following very simple and elementary proof will be of general interest. It can hardly be new, it is so simple and obvious, but at any rate it is not common, for it does not appear in any of the best known treatments which have been consulted.

Consider a particle of mass m which is displaced from its equilibrium position a distance x, and is vibrating in a circle. Then, as is well known, the kinetic energy is equal to the potential energy. For let the elastic restoring force be given by kx. We must then have $kx = mv^2/x$ for steady motion. The potential energy of the particle when at a distance x from the equilibrium position is equal to the work done in displacing it this distance, which equals the distance times the average force, which equals $1/2(kx)\cdot x$. Substituting the above value of kx we have for the potential energy $1/2mv^2$, and the proposition as stated is established. But any such circular vibration may be thought of as composed of two exactly similar linear harmonic oscillations. (When considering energy the phase difference and direction of oscillation is obviously irrelevant.) Therefore we must associate, on the average, half of the total kinetic and half of the total potential energy of the circular vibration with each of the linear vibrations. Since these are equal in the case of the circular vibration they must also be equal in the case of the linear vibration. The result is obviously perfectly general for any linear harmonic oscillation.

Warren Weaver
California Institute of Technology

CARBON DIOXIDE AND INCREASED CROP PRODUCTION

To the Editor of Science: Should one infer from Mr. Harrow's note in the latest issue of Science (May 7, 1920) that the question of "fertilizing" with carbon dioxide were not known to plant-physiologists and agricultural chemists in this country?

If so, it might be worth while to mention that for a number of years, at least for the last ten years, this topic has been the subject of many experiments in Europe, especially in Germany.

The botanists, Hugo Fischer and Adolf Hansen among others, have contributed much to its study. It has even found its place in modern German text-books of plant physiology —for instance in Molisch's "Pflanzenphysiologie"—and no doubt, also in those of agricultural chemistry, such as Schneidewind's "Ernährung der landwirtschaftlichen Kulturpflanzen."

M. W. Senstius

VACANCIES IN THE GRADE OF ASSISTANT CIVIL ENGINEER, U. S. NAVY

APPICATIONS are being received at the Bureau of Yards and Docks, Navy Department, Washington, D. C., to fill 30 vacancies, more or less, in the commissioned grade of assistant civil engineer, U. S. Navy, with the rank of lieutenant (junior grade). The pay and allowances at entrance are approximately $3,200 per annum, with increases up to $9,000, depending upon length of service and promotions.

The candidate must be an American citizen, between the ages of 21 and 34 years on August 1, 1920; must have received a degree in engineering from a college or university of recognized standing; must have had not less than 12 months' practical professional experience since graduation, and must be of good moral character and repute.

The preliminary examination to determine general fitness will be based on papers submitted by the candidates, reaching the Board on or before August 23, 1920, covering college record, testimonials, references and professional experience. The candidate is not required to report in person for the preliminary examination. Physical examination by a board of medical examiners will be made of those candidates who qualify in the preliminary examination.

Those who qualify in the preliminary and physical examinations will take the final oral and written examinations to be held in Washington, D. C., as soon as possible after the preliminary examination papers have been passed on by the Board.

Officers of the Corps of Civil Engineers are detailed principally to the various navy yards and naval stations to supervise the work under the Bureau of Yards and Docks, Navy Department, Washington, D. C., consisting of the design and construction of all the public works of the naval establishment on shore as well as the maintenance and repair of existing structures. The work is exceptionally varied and offers an attractive field for able and ambitious young engineers.

C. W. PARKS,
Chief of Bureau

ARISTOTLE AND GALILEO ON FALLING BODIES

A DRAMATIC event in the history of physics is Galileo's dropping a one pound shot and a hundred pound shot together from the leaning tower of Pisa, to disprove Aristotle's law of falling bodies. In 1913 Professor H. H. Turner of Oxford, in a lecture at the Royal Institution, quoted Galileo's version of Aristotle's law:

> Aristotle said that a weight of ten pounds, for example, fell ten times as fast as a weight of one pound.[1]

To this J. H. Hardcastle replied,[2] "Aristotle never said this at all"; he refers any one who "wishes to find out for himself" to Aristotle's "Physica," Book IV., cap. 8. He does not quote from Aristotle, but quotes from Thomas Aquinas's commentary on the passage in Aristotle to which this reference points. Accepting Hardcastle's statement, G. Greenhill, William Ramsay and Oliver Lodge arrive at the conclusion[3] that Aristotle has been misunderstood. Greenhill interprets Aristotle as teaching "that the terminal velocity of a body in a medium is proportional to the weight," a law "justified by Newton in his experiments in St. Paul's"[4] and exemplified in the motion of "a raindrop or hailstone falling vertically in the air, or of a smoke particle up the chimney"; Galileo discussed an altogether different question, viz., "the start of such a body from rest." Ramsay refers to Ostwald as pointing out that "Aristotle was much more impressed with the retarding effect on the velocity of the mass of the medium through which the falling mass fell, than with the laws of 'free fall.'" Lodge emphasizes "the fact that 'terminal velocity' is the best instance of Newton's first law of motion in actual operation."

[1] Galileo, "Dialogues concerning two New Sciences" (Ed. Crew and De Salvio), New York, 1914, p. 62.

[2] *Nature* [London], Vol. 92, 1914, p. 584.

[3] *Nature*, Vol. 92, pp. 584, 585, 606.

[4] "Principia," Book II., Prop. 40.

These remarks are interesting, but not altogether to the point. Those modern apologists do not actually quote Aristotle, nor do they base their reasoning on what Aristotle actually said.

Aristotle discusses falling bodies in six or more different parts of his "Physica" and "De Cœlo."

1. He considers[5] a body falling through media of different densities—air, water and media indefinitely rare. Then he considers also bodies of different weights falling through the same medium. Endeavoring to disprove the existence of a vacuum, Aristotle says:

> That which is heavier . . ., other things being equal, moves faster through the same space, and indeed faster according to the ratio of the magnitudes of the things, so that this must happen also through a vacuum. But this is impossible; for why should it move faster? In a plenum this is necessarily true, because the larger moves more rapidly by its power of greater penetration.

Thus, according to this Aristotelian passage, not only do the larger bodies move faster through a medium, but they would move faster even through a vacuum, if such existed.

2. Aristotle asserts[6] that each of the bodies constituting the universe was originally at rest (as taught by Anaxagoras), that each was heavy or light and had power to move.

> For suppose *A* without weight, but *B* possessing weight; and let *A* pass over a space *CD*, but *B* in the same time passes over a space *CE*—for that which has weight will be carried through the larger space. If now the heavy body be divided in the proportion that space *CE* bears to *CD*, . . . and if the whole is carried through the whole space *CE*, then it must be that a part in the same time would be carried through *CD*. Consequently the body without weight and the one possessing weight pass over the same distance, which is impossible.

Here Aristotle's law is applied to bodies initially at rest.

3. Aristotle argues[7] that "if there were an unlimited increase in the weight, there would be also an unlimited increase in velocity." The volume of a falling body is specially considered in "De Cœlo," Book IV., cap. 1:[8]

4. In "De Cœlo," Book I., cap 6,[9] we find:

> If such and such a weight is moved so and so far in such and such a time, then some larger weight will be moved through the same distance in still shorter time, shorter in the inverse ratio of the weights. . . . A limited weight can pass over any limited line in a limited time.

5. In "De Cœlo," Book IV., cap. 2,[10] Aristotle argues, likewise, that the more fire will proportionally move upward with greater speed and the less fire with less speed, and similarly for the downward motion of more gold or more lead. Here, as in most other passages, the shapes of the moving bodies are not considered.

The above shows that Aristotle considered his law applicable when the motion took place from rest as in (2), when there was no upper limit to the weight that the moving body may have as in (3), when the time of motion may be reduced or increased as in (4), and when the moving bodies are different weights of any metal, like gold or lead, as in (5). No restriction is placed by Aristotle to the combination of some or all of these four conditions in one and the same motion. To our surprise, he was willing to apply his law even to motion in a vacuum (were a vacuum possible) as is seen in (1). It appears therefore that Aristotle allowed his law a generality of application which certainly did include the special conditions under which Galileo performed his experiment of dropping a one-pound shot and a hundred-pound shot through the air from the leaning tower.

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[5] "Physica," Book IV., cap. 8. We are using Carl Prantl's "Aristoteles' Werke. Griechisch und Deutsch," Bd. I., Leipzig, 1854, pp. 187–191.

[6] "De Cœlo," Book III., cap. 2; Prantl, Vol. 2, pp. 203–205.

[7] "De Cœlo," Book I., cap. 8; Prantl, Vol. 2, p. 65.

That body is heavier than another which, in an equal bulk, moves downward quicker.

[8] Prantl, Vol. 2, p. 243.

[9] Prantl, Vol. 2, p. 47.

[10] Prantl, Vol. 2, p. 249.

SPECIAL ARTICLES

AN ACCURATELY CONTROLLABLE MICROPIPETTE

A NUMBER of pipette devices have been employed for the injection or extraction of minute quantities, which have served their purpose quite satisfactorily. Among these may be mentioned the several methods described by Toldt,[1] Barber[2] and Chambers.[3] However, in certain recent work I was unable to use with the necessary accuracy any of these methods and so undertook to construct a micropipette which could be very reliably and precisely controlled.

The simple apparatus now being used serves my needs so surprisingly well that I offer this description of it hopeful that the method will be of service to others. By its use I have succeeded in extracting the micronucleus from the ciliate *Euplotes*, have injected very minute quantities of various solutions into the cytoplasm and macronucleus and have induced the formation of vacuoles near the contractile vacuole in such manner as to obtain significant data on the behavior and function of the latter structure. An account of these results will be published in later papers; I shall here only describe the method employed. I am indebted to Professor S. O. Mast for several important suggestions in the construction of the apparatus.

The general principle involved in the operation of this mechanism is the inducement at will either of large or of very delicate changes in a given volume of mercury by means of a small steel needle attached to a finely threaded thumb-screw.

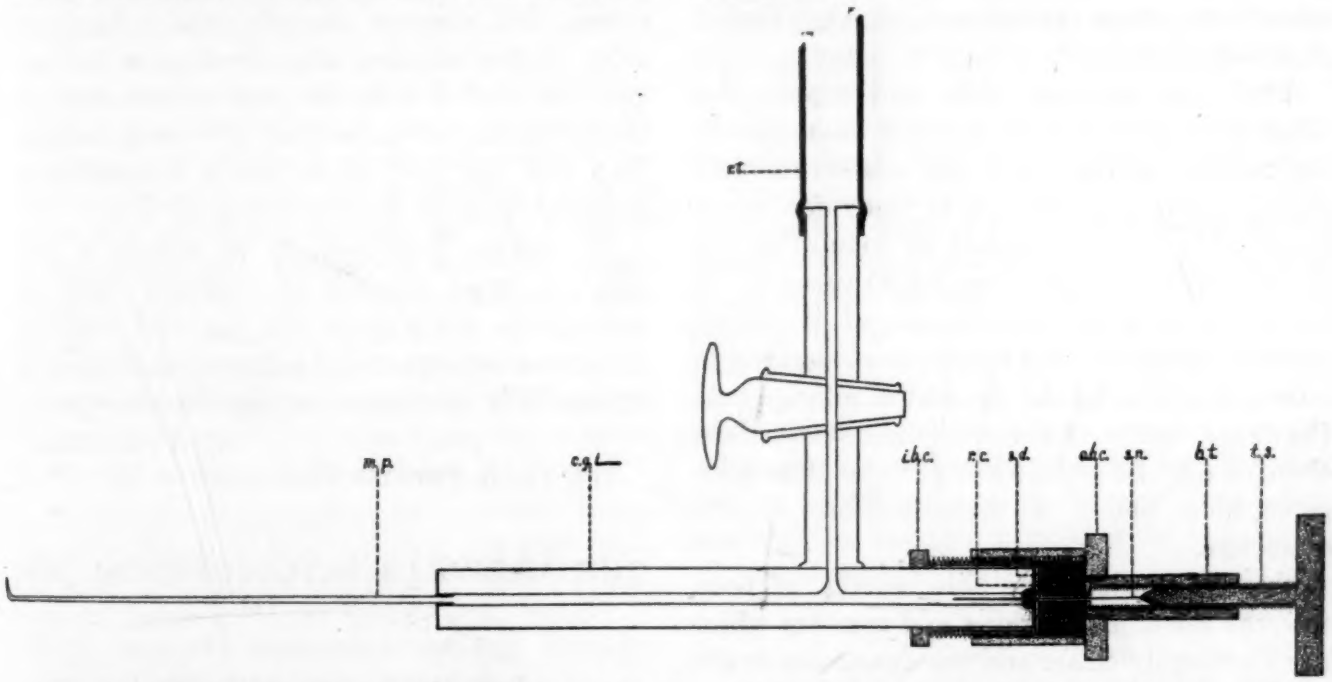

FIG. 1. *bt.*, brass tube; *c.g.t.*, capillary tube; *i.b.c.*, "inner" brass cap; *m.p.*, micropipette; *o.b.c.*, "outer" brass cap; *r.c.*, rubber cylinder; *r.t.*, rubber tube; *s.d.*, steel disk; *s.n.*, steel needle; *t.s.*, thumb-screw.

The mercury is contained in a capillary glass tube 7 cm. in length and 6 mm. in diameter with a bore of about 1 mm. Into one end of the tube is sealed the micropipette (*m.p.*) and over the other end an "inner" brass cap (*i.b.c.*), as shown in Fig. 1.

The end of this "inner" cap is covered and sealed by a thin steel disk (*s.d.*) having a central projection which inserts a short distance into an enlargement of the capillary bore. Through the center of the disk is a hole of

[1] Toldt, "Die Injection unter messbarem Drucke," *Archiv. f. Mikr. Anat.*, 1869, 5, 167, Taf. XI.

[2] Barber, M. A., "The Pipette Method in the Isolation of Single Microorganisms and in the Inoculation of Substances into Living Cells," *The Philippine Jour. Sci.*, Sec. B, Trop. Med., 9, 307.

[3] Chambers, R., "The Microvivisection Method," *Biol. Bull.*, 1918, 34, 121.

size just convenient to accommodate the entrance of the steel needle into the capillary tube. The needle, 3 cm. long and about 2/5 mm. in diameter, is soldered on to a finely-threaded thumb-screw (*t.s.*) which operates in a brass tube (*b.t.*). This tube is screwed firmly into the base of an "outer" brass cap (*o.b.c.*). In the inner end of the brass tube, the needle passes through a hole having a diameter the same as that in the steel disk. Into the "outer" cap is fit very closely a soft rubber cylinder (*r.c.*), in length one half that of the cap, through the center of which passes the needle. Inserting the needle into the hole in the steel disk, the "outer" cap is now screwed tightly on to the "inner" cap.

The device is supported and adjusted on the microscope stage by means of the Barber pipette-holder.

After the capillary tube and pipette are filled from a column of mercury contained in the rubber tubing (*rt.*), the system is then closed by the stopcock and is ready for operation. This is accomplished by regulating the thumb-screw which is threaded 60 turns to the inch. Very slight movements of it induce gradual changes of the meniscus of mercury in either direction in the tip of the micropipette (having a lumen of about five microns); these changes may be so delicate as to be almost imperceptible under a magnification of 400 diameters.

Two precautions are here worthy of note, viz., the use of glass tubing and mercury which are thoroughly clean, and the avoidance of air-bubbles anywhere within the system. To clean glass tubing, I have found the following method very effective: after sealing one end of the tube, put into it a few drops of 95 per cent. alcohol and a like amount of concentrated HNO_3. Upon adding a drop or two of H_2SO_4, an explosive reaction occurs which apparently oxidizes thoroughly any substances adhering to the surface of the glass. (The tube, of course, should be turned away from one's face before adding the H_2SO_4.) Break off the sealed end and wash the tubing well with distilled water.

To hasten the filling of the system with mercury and to remove air that may appear, it is advisable to fill nearly full the capillary tube (and add a drop of dust-free, distilled water which can be forced through the pipette point more easily than mercury) just before sealing in the pipette.

It is advantageous, also, to have the shank of the pipette fit fairly well the bore of the tube; air-bubbles are then less likely to appear in the sealing-wax between the shank and the surface of the bore.

The needle-pipette operates inside a moist chamber similar in design to that described by Chambers (*loc. cit.*). Distilled water or solutions of any sort for injection purposes may be drawn into the pipette after the mercury has been forced to the tip by turning the thumb-screw, then dipping the tip into a hanging drop of the solution and drawing a desired quantity of this into the pipette by reversing the movement of the screw. Obviously, cleansing with distilled water, which is sometimes essential, may be done in a similar way.

To extract cytoplasm or to remove a nucleus, a small amount of distilled water is drawn into the pipette, the tip then inserted into the organism and the operation completed by carefully manipulating the thumb-screw.

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THE AMERICAN PHILOSOPHICAL SOCIETY. III

SATURDAY, APRIL 24

Executive Session—9:30 o'clock

Stated Business.—Candidates for membership balloted for. Appropriations for the ensuing year passed. Annual address of the president.

Morning Session—10 o'clock

George Ellery Hale, Ph.D., Sc.D., LL.D., vice-president, in the chair

The problem of the evolution of the solar system: Ernest W. Brown, Sc.D., professor of mathematics, Yale University.

Certain aspects of recent spectroscopic observations of the gaseous nebulæ which appear to establish the relationship between them and the stars: W. H. Wright, astronomer, Lick Observatory.

(Introduced by Professor Robert G. Aitken.) The paper summarizes in non-technical terms the evidence afforded by a study of the stellar condensations in the planetary or small gaseous nebulæ, which are shown to be spectroscopically identical with stars of the Wolf-Rayet group (Pickering's Class O). A brief account is given of some of the present day conceptions of stellar evolution, for the purpose of indicating the somewhat critical nature, with respect to these ideas, of the relationship indicated. A complete account of the investigation, of which the paper summarizes a part, is given in Volume XIII., part 6, of the Publications of the Lick Observatory.

The Einstein theory: EDWIN PLIMPTON ADAMS, Ph.D., professor of physics, Princeton University. Following Newton's statement of the law of universal gravitation, the goal of all physical explanations of natural phenomena was to reduce them to actions at a distance between elements. After Maxwell showed that electric and magnetic phenomena could be accounted for by a system of pressures and tensions in a universal medium—the ether—the goal changed, and the attempt was made to explain physical phenomena by direct action through a medium. Attempts to account for gravitational forces, however, in this way met with little success. The extension, by Einstein, of the principle of relativity and the resulting revision of the concepts of space and time, led to Einstein's interpretation of gravitation as a property of space itself when modified by the presence of matter.

The results of geophysical observations during the solar eclipse of May 29, 1919, and their bearing upon the Einstein deflection of light. (Illustrated): LOUIS A. BAUER, Ph.D., Sc.D., director of the department of terrestrial magnetism, Carnegie Institution of Washington. This paper is a continuation of the one presented at a stated meeting of the society on February 6, 1920. In that paper[1] a résumé was given of the geophysical and astronomical observations concerning the solar eclipse of May 29, 1919, and the Einstein effect made by the various expeditions sent out by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington and the various astronomical expeditions sent out by Great Britain, the Rio Janeiro Observatory, and the Smithsonian Institution. It was shown how the results of the geophysical observations may have an important bearing upon the complete interpretation of the astronomical observations showing the deflections of light during the eclipse. A brief analysis of the light deflections was given and it was pointed out that there were non-radial effects of such a systematic nature that they could not be accounted for by errors of observation. The present paper gives the results of a special study of the cause of the non-radial effects of the light deflections observed by the British expedition at Sobral, Brazil. It is shown that these non-radial effects may be completely accounted for by incomplete elimination of differential refraction effects in the earth's atmosphere. The same cause may apparently also explain why the observed radial deflections of light exceeded, on the average, by about 14 per cent. the amounts predicted on the basis of the Einstein law of gravitation.

[1] "Observations in Liberia and Elsewhere of the Total Solar Eclipse of May 29, 1919, and Their Bearing on the Einstein Theory."

The high voltage corona in air: J. B. WHITEHEAD, professor of applied electricity, Johns Hopkins University. (Introduced by Dr. Pender.) The paper describes the nature of the corona and recent studies of the laws governing its appearance in high voltage circuits. Its influence as a limiting factor in long distance transmission occurs through deterioration of insulation and a leakage loss of power between the high voltage lines. The appearance of corona on a clean round wire is very sharply marked and may be used for the measurement of high alternating voltages to a degree of accuracy not heretofore possible. Experiments and observations on the corona voltmeter, an instrument devised for this purpose, are recorded; and an example of the instrument, suitable for voltages up to 300,000 volts, is described.

The velocity of explosive sounds: DAYTON C. MILLER, D.Sc., professor of physics, Case School of Applied Science, Cleveland. In 1918–1919 the writer had the privilege of making an extended series of experiments on the pressure waves from large guns in action, at Sandy Hook Proving Ground. One series of experiments was for the purpose of determining the variation in the velocity of the sound of the gun explosion as measured from the muzzle outward, and for the determination of the velocity of sound in free air. Most of the experiments were made in connection with 10-inch and 12-inch rifles, though a few were made with 6-inch and 8-inch guns. The amount of powder charge and the value of the internal pressure developed in the gun are taken into account. The sounds were received by means especially constructed carbon-granule microphones, while others

were of a very sensitive type. The records were made by an especially constructed moving-film camera in connection with a string-galvanometer capable of recording from six stations simultaneously, of the type used by our army for sound-ranging. Stations were located at the muzzle of the gun, and at points in front of the guns at distances of about 100, 200, 300, 400, 500, 600, 1,000, 2,000, 7,300 and 21,000 feet, six of these stations being used at one time. The locations were determined with precision. Meteorological observations were made by special observers in the distant stations and on the field near the guns, at the time of the experiments and continuous records were made at the Proving Ground Headquarters and at the United States Weather Bureau Station. These observations covered temperature, barometric height, humidity, wind velocity and wind direction. Measurements were also made of the velocity of the sound at a series of stations located on a line at right angles to the line of fire, and on a line at 45° to one side of the line of fire. In all, seventy-two sets of velocity determinations were made, eleven sets extending to the most distant stations at 21,000 feet from the gun, while the other sets relate to various groups of stations within 2,000 feet of the gun. Heretofore there has been a general impression that explosive sounds travel much farther than do ordinary sounds, the velocity being perhaps several times the normal velocity. These experiments show conclusively that the velocity at a distance of one hundred feet from a 10-inch gun is about 1,240 feet per second, or 22 per cent. above normal; at two hundred feet from the gun the velocity is only about 5 per cent. above normal. For all distances above five hundred feet from the gun the velocity of the explosive sound from the largest sized gun is practically normal. The value of the velocity of sound over the long range of 21,000 feet has not yet been calculated with all corrections applied, the preliminary value is in entire agreement with other determinations, and is about 1,089 feet per second at the freezing temperature. It is expected that the final value will be of a precision equalling the best heretofore obtained.

The U. S. navy MV-type of hydrophone as an aid and safeguard to navigation: Harvey C. Hayes, Ph.D., U. S. Naval Engineering Experiment Station, Annapolis. (Introduced by Professor John A. Miller.)

The transient process of establishing a steady alternating electric current on a long line from laboratory measurements on an artificial line: A. E. Kennelly, A.M., Sc.D., director, Research Division, Electrical Engineering Department, Massachusetts Institute of Technology, and U. Nabeshima. When a power-transmission electric conducting line is switched on to the generator at the power house, the alternating-current on that line settles down to a final state, under steady load, in a time which is theoretically indefinitely long, but which is usually practically covered in a small fraction of a second. The paper discusses the transient phenomena which occur along the line during this process of upbuilding the final current and voltage. The subject has been studied theoretically by a number of writers; but very few practical observations have been published concerning this transient state. It is known that the current and voltage do not build up steadily and continuously, but advance by little jumps which occur at regular short intervals of time, accompanying successive reflections of electromagnetic waves from one end of the line to the other. The authors present in the paper a number of observations which have been secured photographically, of the rise of voltage and current on a long artificial electric power-transmission line in the laboratory, and have compared the observed rates of growth with those which are indicated by theory, with a fairly satisfactory agreement. The observed results indicate the manner and mechanism by which electric power may be conceived of as being transmitted along such a line.

The strephoscope: N. W. Akimoff. (Introduced by Professor Eric Doolittle.)

New features in the eclipsing variable U Cephei: R. S. Dugan, professor of astronomy, Princeton University. (Introduced by Professor H. N. Russell.)

Arthur W. Goodspeed

(To be concluded)

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